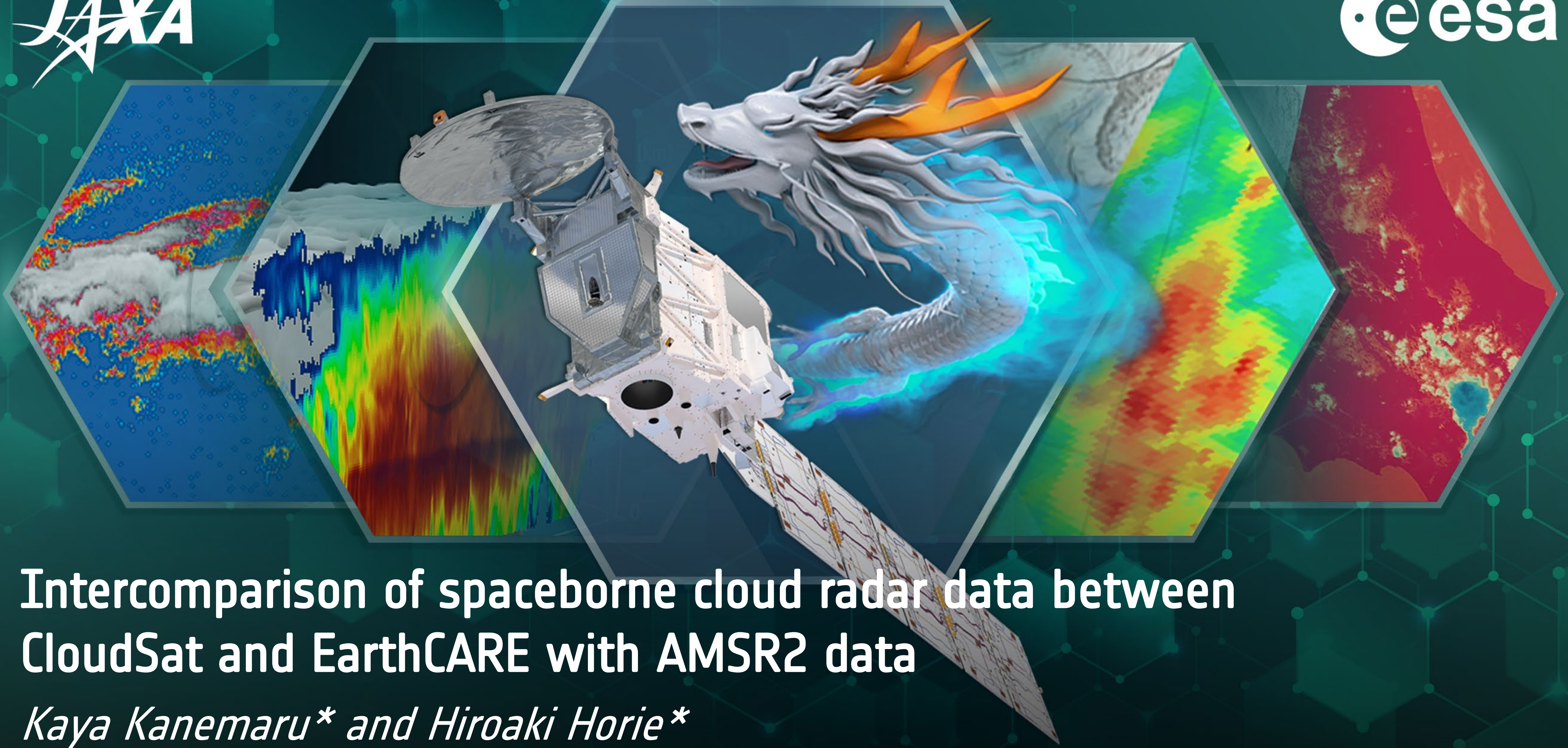

Intercomparison of spaceborne cloud radar data between CloudSat and EarthCARE with AMSR2 data

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**NICT*

2nd ESA-JAXA EarthCARE In-Orbit Validation Workshop

17 – 20 March 2025 | ESA-ESRIN | Frascati (Rome), Italy

Background and purpose

2006/06 – 2023/12

CloudSat CPR

Gap

2024/06 – NOW

EarthCARE CPR

2013 – 2019

2012/07 – NOW

GCOM-W AMSR2

Evaluation of EarthCARE CPR (EC-CPR) data with CloudSat CPR (CS-CPR) data is useful for checking data quality. It is, however, since CloudSat mission was ended at 2023/12, **EarthCARE CPR data cannot be directly compared by CloudSat CPR data**. Here, intercomparison of CPRs between CloudSat and EarthCARE is conducted with GCOM-W AMSR2 sea surface wind (SSW) data as a reference.

	CloudSat	GCOM-W	EarthCARE
Equatorial crossing time	13:30 (asc)	13:30 (asc)	14:00 (des)

Method: Matchup between σ_m^0 and SSW

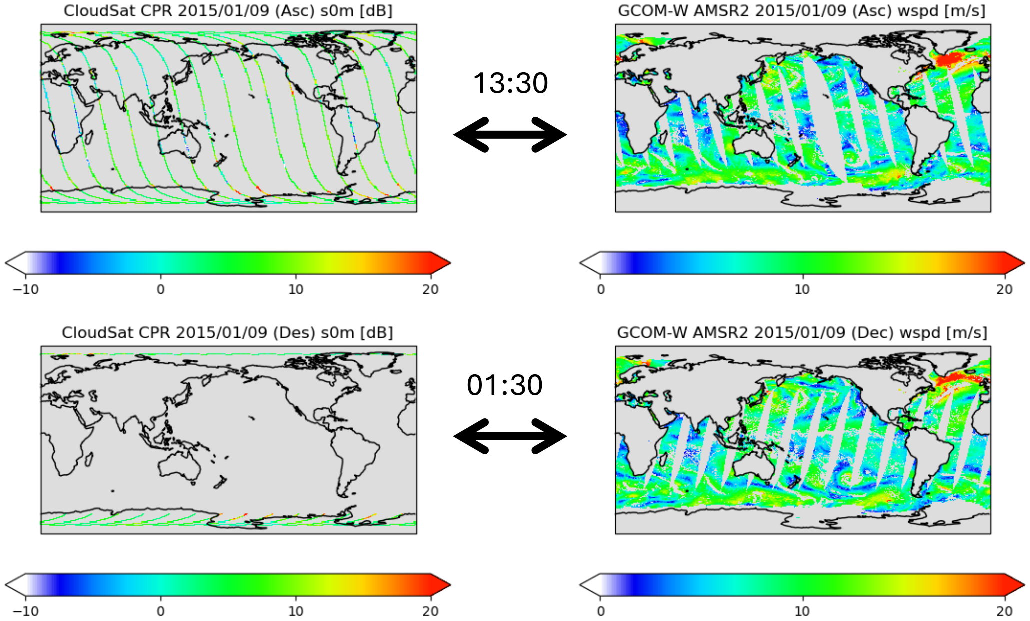
2015/01/09

2025/01/09

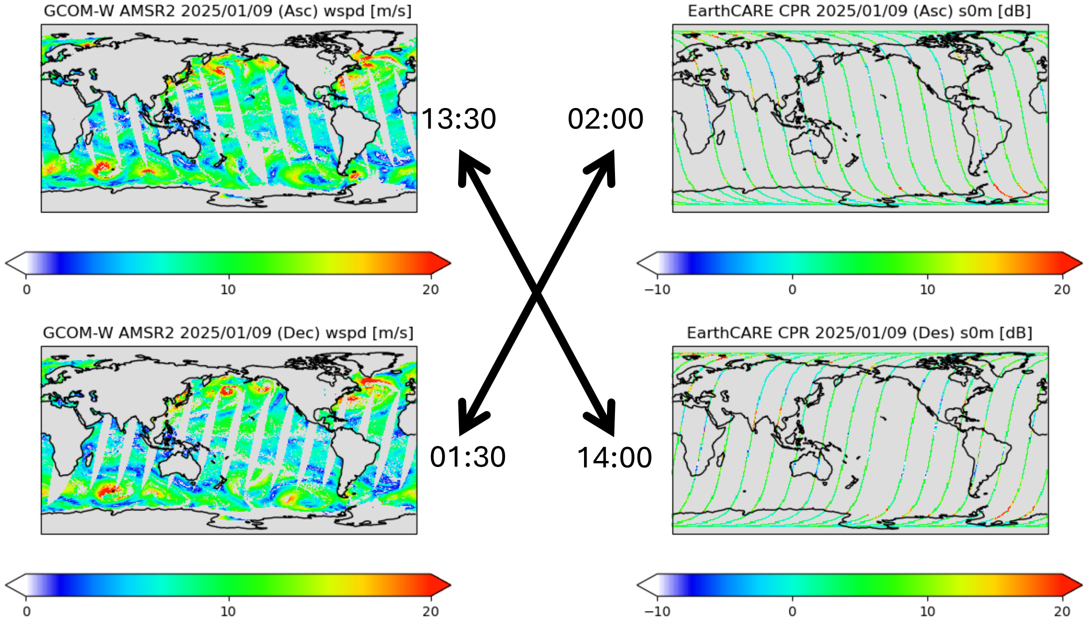
CloudSat CPR s0m [dB]

GCOM-W AMSR2 SSW [m/s]

EarthCARE CPR s0m [dB]



After 2012, CPR was DO-Op (Daylight-Only Operations) mode



Note that σ_m^0 is gridded onto 0.25 deg 0.25 deg.

AMSR2 AS-ECV in V8.2 (Remote Sensing Systems)
CS-CPR L1B in R05 (CloudSat DPC)
EC-CPR L1B in vCa (JAXA/NICT)

Method

Monitoring stability of radar calibration

$$\sigma_m^0 \approx \sigma^0(\theta_z, \lambda, U_{10})$$

θ_z: incidence angle
λ: wavelength
U_{10}: sea surface wind

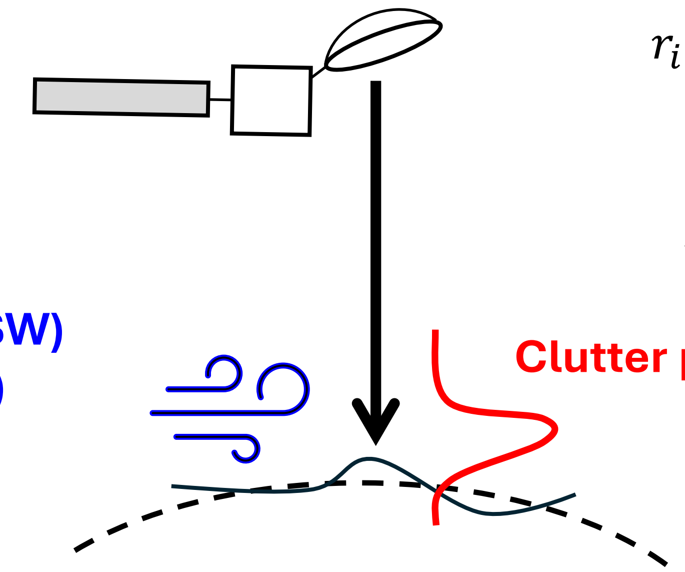
Reconstruction of clutter pattern P_{sfc}

$$P_{\text{sfc}}(r_i - r_{\text{DEM}}) = P_r(r_i)$$

$$r_i = \text{rangeToFirstBin} + (i-1) \times \text{rangeBinSize}$$

i: range-bin # (1 start)

$$r_{\text{DEM}} \simeq \text{rangeToIntercept} - \frac{\text{elevation}}{\cos \theta_z}$$



Kanemaru et al. (2024, JTECH)
https://dx.doi.org/10.1175/JTECH-D-23-0151.1

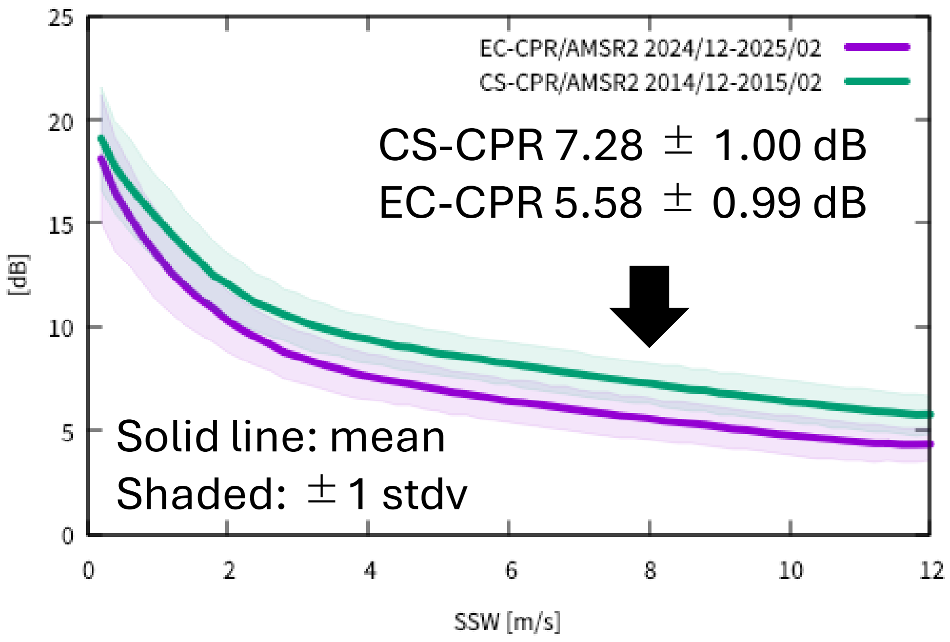
Kanemaru et al. (2020, TGRS)
https://dx.doi.org/10.1109/TGRS.2019.2963090

Results: σ_m^0 vs. SSW

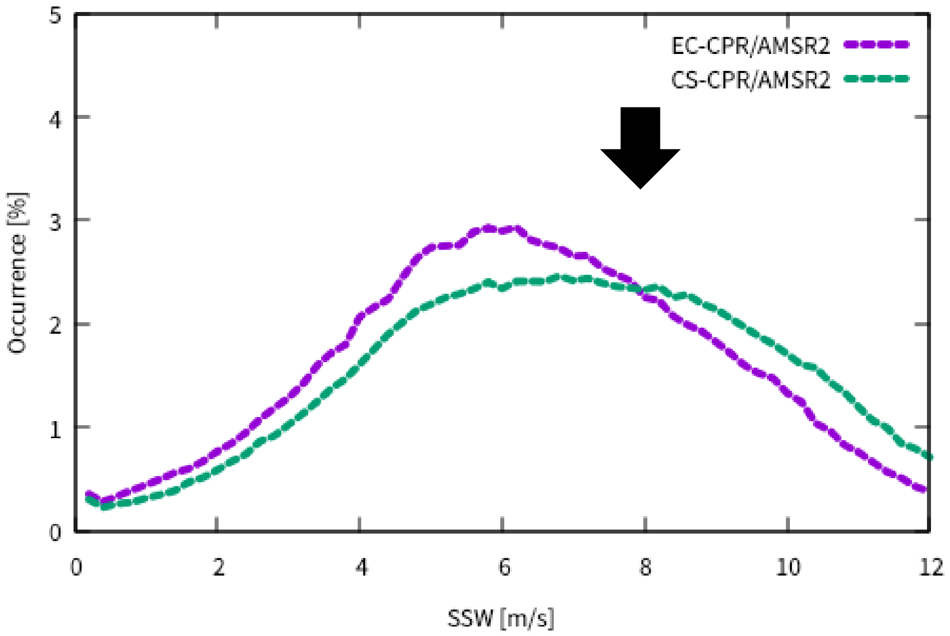
EarthCARE(EC)-CPR: 2024/12/01-2025/02/28 (vCa)
CloudSat(CS)-CPR: 2014/12/01-2015/02/28 (R05)

Clear-sky is defined as a simple judgement using P_r and P_n

AMSR-2 SSW vs. s0m in clear-sky



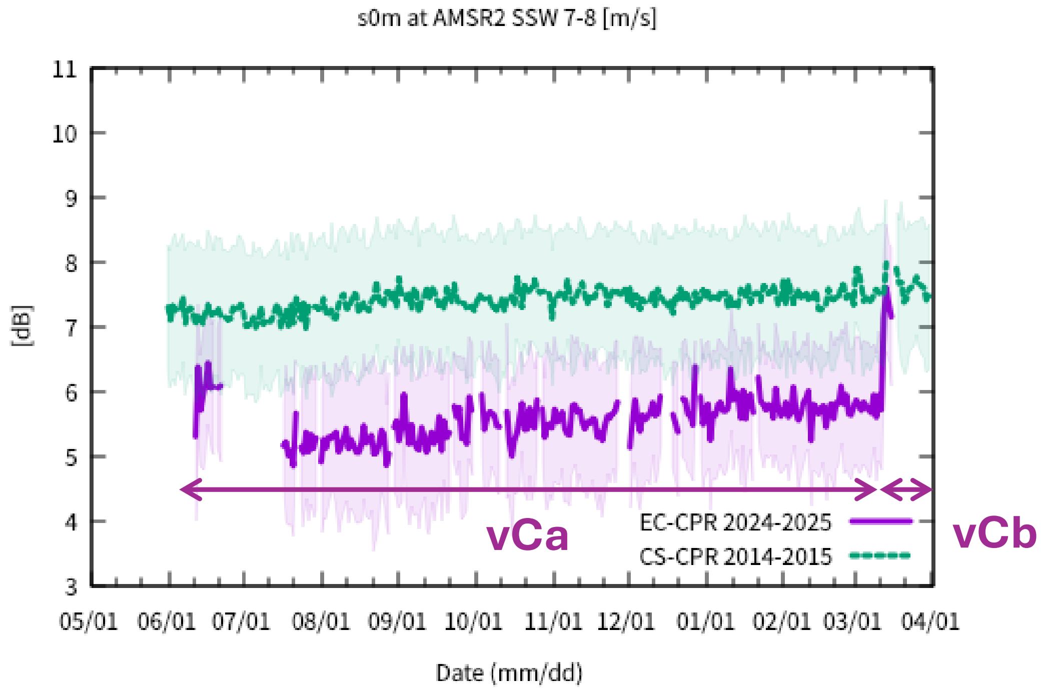
Collocated frequency



σ_m^0 measured by EC-CPR (vCa) is 1.70 dB lower than to that by CS-CPR.

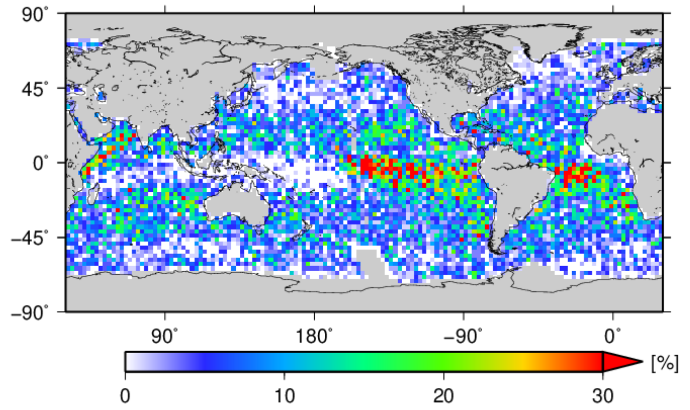
Results: Timeseries of σ_m^0 at SSW 8 m/s

Time series of σ_m^0 by EC-CPR is stable with time.
From vCa to vCb, σ_m^0 level increase 1.60 dB.

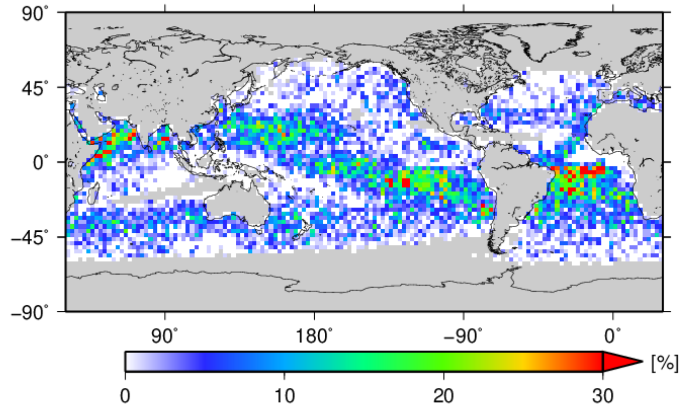


Solid line: mean
Shaded: $\pm$1 stdv

CS-CPR/AMSR2 collocated frequency (2014/12-2015/02)



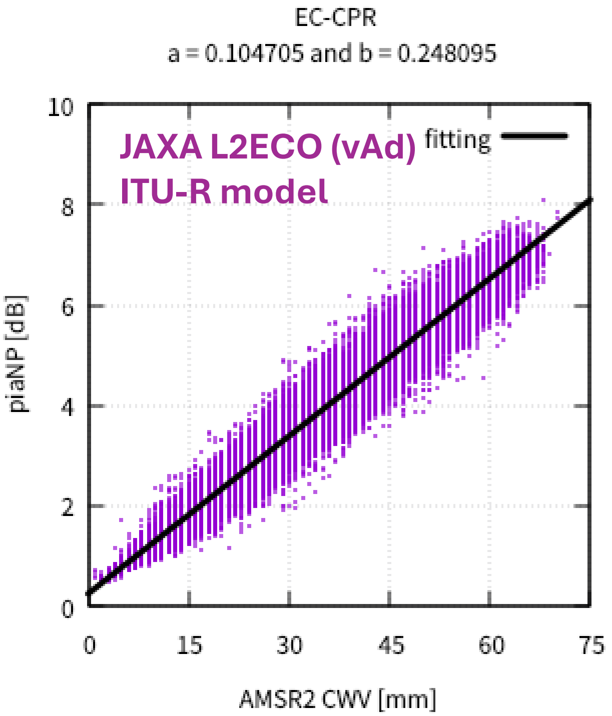
EC-CPR/AMSR2 collocated frequency (2024/12-2025/02)



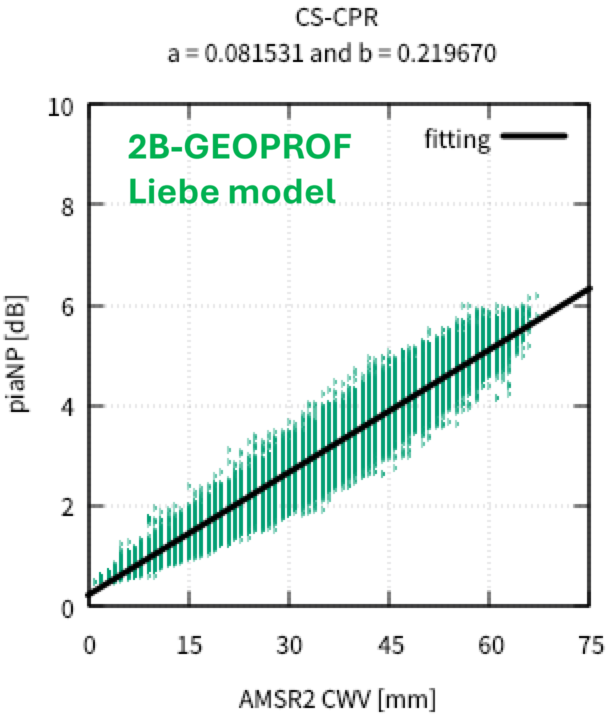
SSWs from 7 to 8 m/s are frequently observed over subtropical and mid-latitude oceans.

Results: Attenuation due to atmospheric gas

2025/01/01



2015/01/01



To evaluate impacts of atmospheric gas attenuation, We tried to use L2 products (2B-GEOPROF and JAXA L2ECO).
But, we found the difference in path integrated attenuation due to atmospheric gas (PIA_{gas}). This difference is caused by the difference in the model of atmospheric gas (especially water vapor) absorption.

To use the same formula of PIA_{gas}, a fitting result obtained from **2B-GEOPROF's PIA_{gas} and AMSR2 CWV** data, is used *ad hoc*,

$$\mathrm{PIA}_{\mathrm{gas}} \approx 0.0815 \times \mathrm{CWV}_{\mathrm{AMSR2}} + 0.220$$

(2015/01/01 one-day)

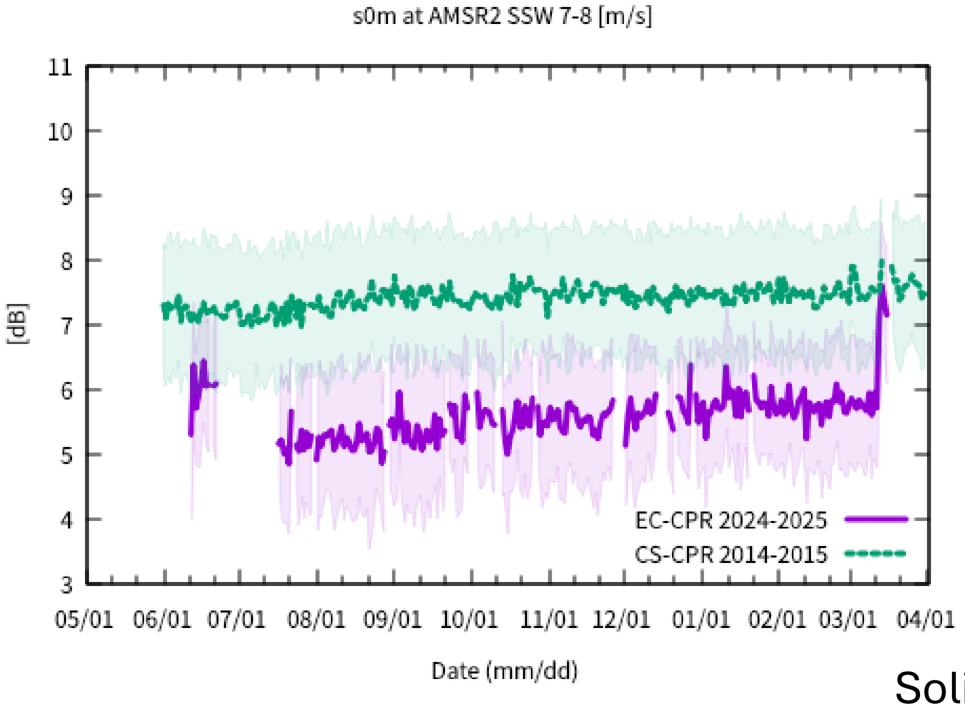
$$\sigma^0 = \sigma_m^0 + \mathrm{PIAgas}$$

Results: Timeseries of σ_m^0 and σ^0 at SSW 8 m/s

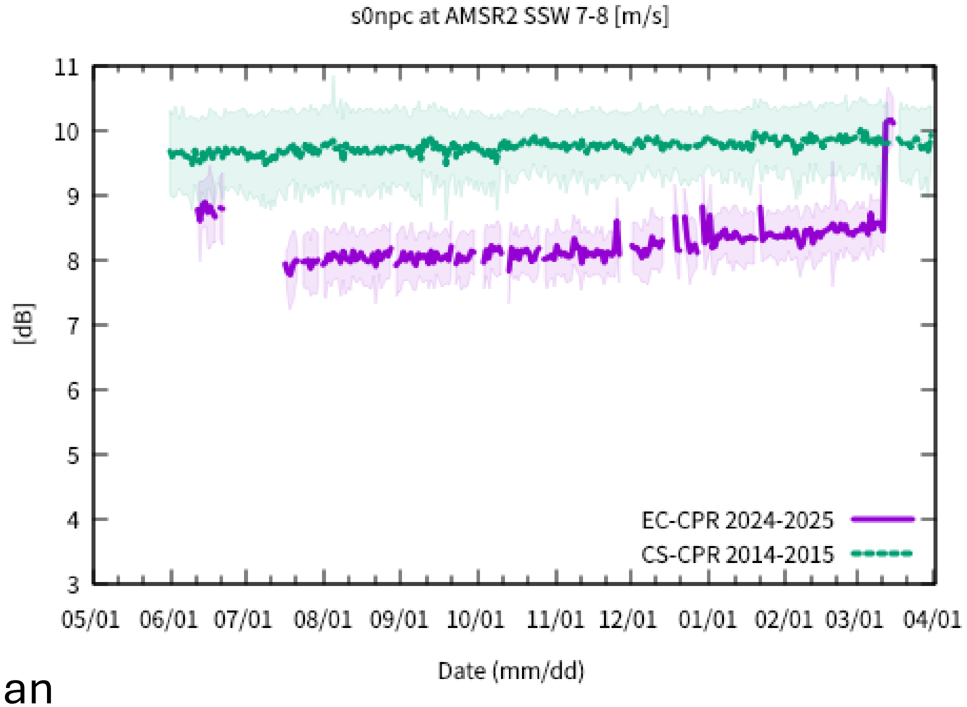
Time series of σ_m^0 by EC-CPR is stable with time. From vCa to vCb, σ_m^0 level increase 1.60 dB.

Except for change in configuration, σ^0 level of EC-CPR is stable with time. Standard deviations also become small because of ad-hoc PIA_{gas} correction.

σ_m^0



σ^0



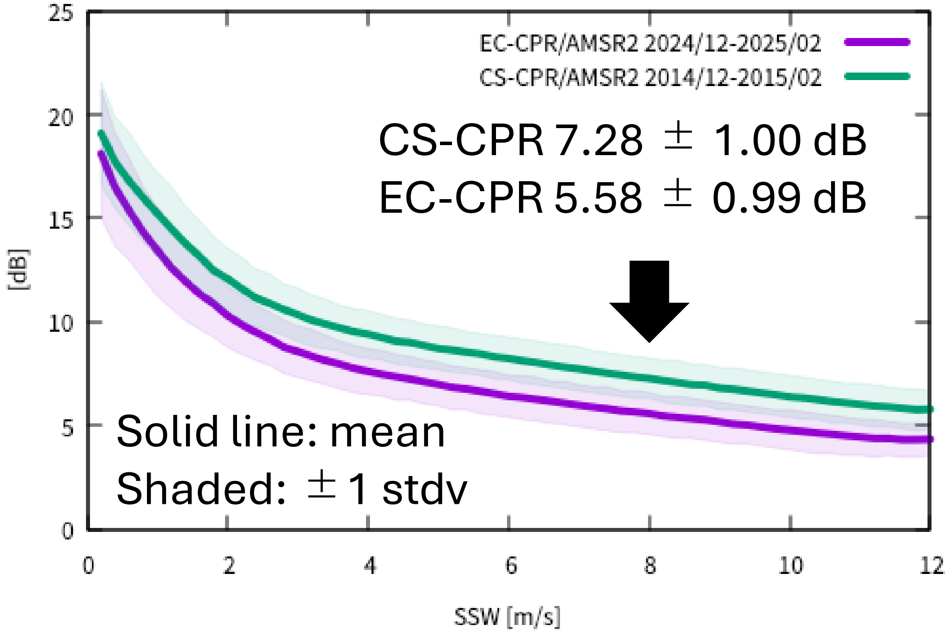
Solid line: mean
Shaded: $\pm$1 stdv

Results: σ_m^0 and σ^0 vs. SSW

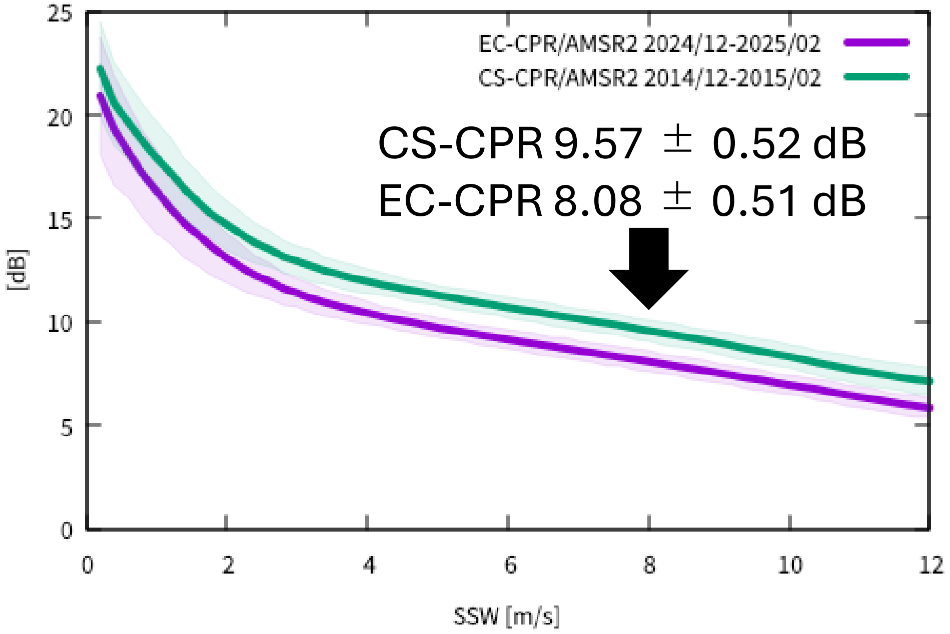
EarthCARE(EC)-CPR: 2024/12/01-2025/02/28 (vCa)
CloudSat(CS)-CPR: 2014/12/01-2015/02/28 (R05)

Clear-sky is defined as a simple judgement using P_r and P_n

AMSR-2 SSW vs. s0m in clear-sky



AMSR-2 SSW vs. s0 in clear-sky



σ_m^0 measured by EC-CPR (vCa) is 1.70 dB lower than to that by CS-CPR.
σ^0 measured by EC-CPR (vCa) is 1.49 dB lower than to that by CS-CPR.

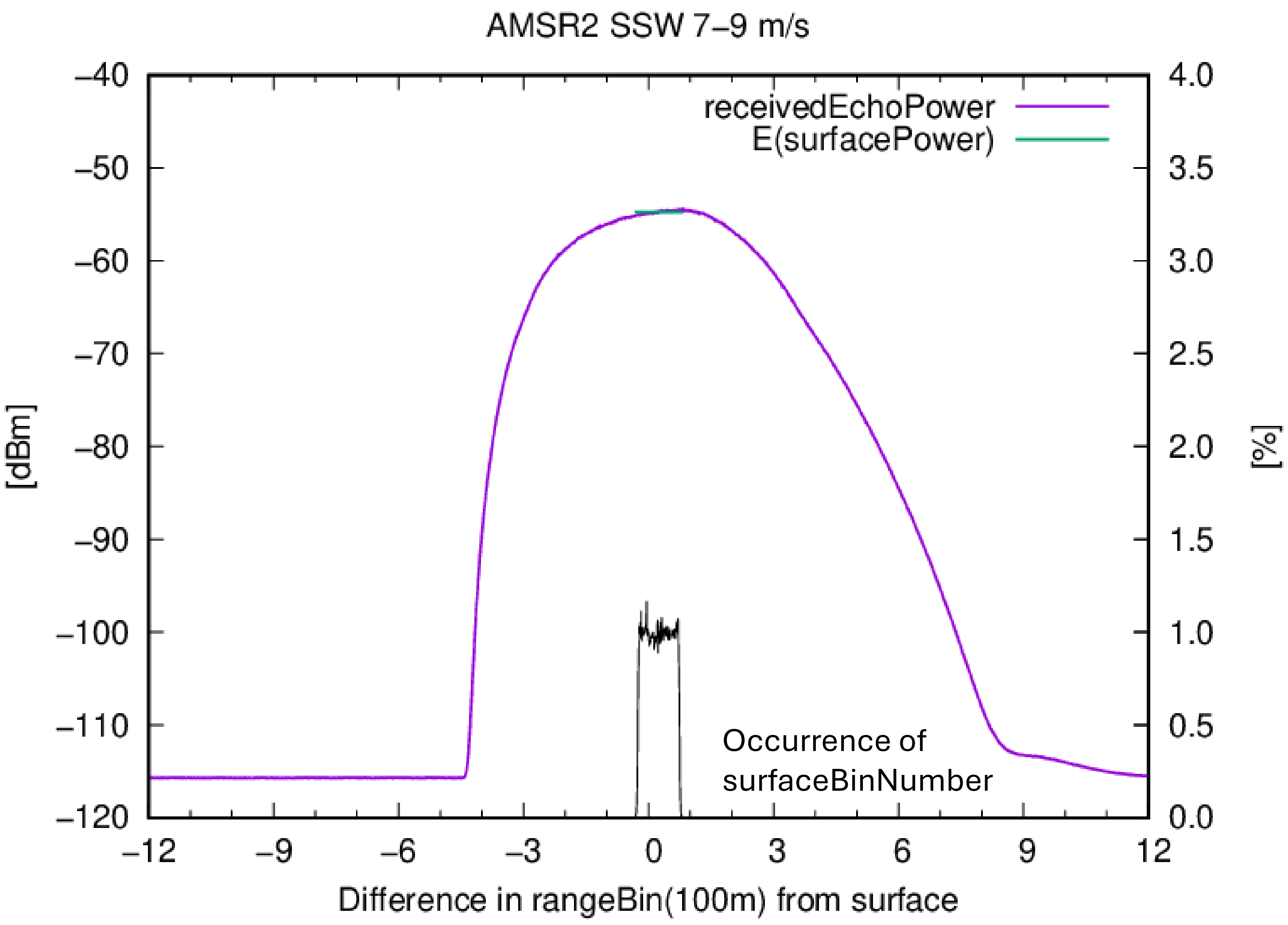
Summary

EC-CPR L1 products in public version (vCa/vCb) are intercompared with CS-CPR L1 products by using GCOM-W AMSR2 data as a reference.

- σ_m^0 (σ^0) of EC-CPR in vCa is 1.70 (1.49) dB lower than that of CS-CPR in R05.
- Except for change in configuration, σ^0 level of EC-CPR is stable with time.
- Since σ_m^0 of EC-CPR increase 1.60 dB from vCa to vCb, the difference in σ_m^0 between EC-CPR and CS-CPR is almost removed after the minor update.
- Future tasks are listed below:
  - -0.3 dB bias due of coarse discrete range sampling for EC-CPR's σ_m^0
  - Re-consideration of calibration factor
  - Revision of attenuation correction of atmospheric gas in JAXA L2ECO


JAXA
esa

Results: Reconstructed clutter pattern



2025/01/01-2025/01/31 (1 month)

AMSR2 sea surface wind: 7-9 m/s
AMSR2 column water vapor : < 40 mm
Latitude: -40 to 40 (avoid sea ice)

$\mathrm{Max}[E[P_r(r_i - r_{\mathrm{dem}})]]$ = -54.55 [dBm]

$E[P_r(r_{i,\mathrm{sfc}})]$ = -54.81 [dBm]

$E[P_{\mathrm{sfc,L1}}]$ = -55.20 [dBm]

$$P_{\mathrm{sfc,L1}} = 10\log_{10}\left(\frac{1}{3}\sum_{j=i_{\mathrm{sfc}}-1}^{i_{\mathrm{sfc}}+1} 10^{0.1P_r(r_j)}\right)$$

CS-CPR algorithm adopts peak miss bias correction. But, EC-CPR algorithm does not adopt the bias correction. The bias for EC-CPR is estimated to be from -0.65 dB to -0.26 dB.

ITU-R (ITU Radiocommunication Sector)
Recommendation ITU-R P.676-10 (09/2013)

Annex 2

Approximate estimation of gaseous attenuation in the frequency range 1-350 GHz

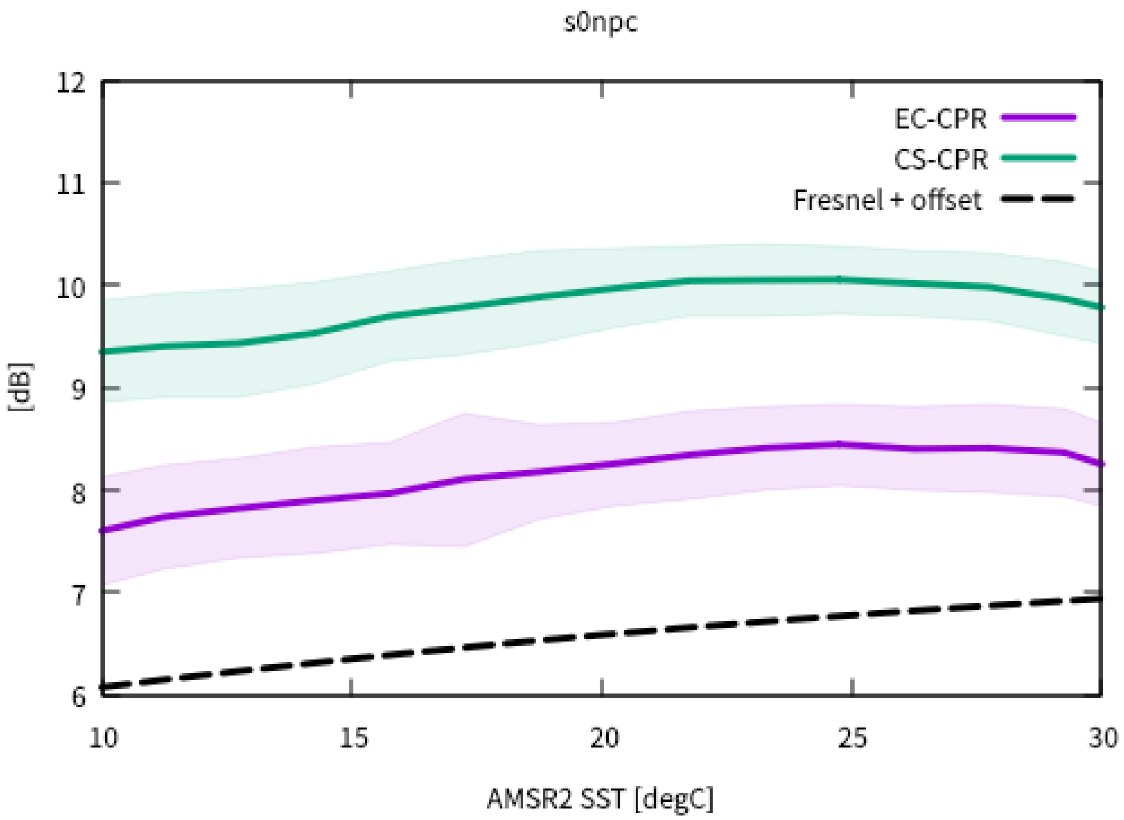
This Annex contains simplified algorithms for quick, approximate estimation of gaseous attenuation for a limited range of meteorological conditions and a limited variety of geometrical configurations.

1 Specific attenuation

The specific attenuation due to dry air and water vapour, from sea level to an altitude of 10 km, can be estimated using the following simplified algorithms, which are based on curve-fitting to the line-by-line calculation, and agree with the more accurate calculations to within an average of about ±10% at frequencies removed from the centres of major absorption lines. The absolute difference between the results from these algorithms and the line-by-line calculation is generally less than 0.1 dB/km and reaches a maximum of 0.7 dB/km near 60 GHz. For altitudes higher than 10 km, and in cases where higher accuracy is required, the line-by-line calculation should be used.

For dry air, the attenuation γ_o (dB/km) is given by the following equations:

s0 at SSW 8 m/s with correction of PIA_{gas}
(2024/12-2025/02)



σ^0 has SST dependency because σ^0 is closed related with the Fresnel reflection coefficient.

$|\Gamma|^2(SST, SSS = 35)$ in decibel space plus offset